

10 000-hr Cyclic Oxidation Behavior of 68 High-Temperature Co-, Fe-, and Ni-Base Alloys Evaluated at 982 °C (1800 °F)

Power systems with operating temperatures in the range of 815 to 982 °C (1500 to 1800 °F) frequently require alloys that can operate for long times at these temperatures. A critical requirement is that these alloys have adequate oxidation resistance. The alloys used in these power systems require thousands of hours of operating life with intermittent shutdown to room temperature. Intermittent power plant shutdowns, however, offer the possibility that the protective scale will tend to spall (i.e., crack and flake off) upon cooling, increasing the rate of oxidative attack in subsequent heating cycles. Thus, it is critical that candidate alloys be evaluated for cyclic oxidation behavior. It was determined that exposing test alloys to ten 1000-hr cycles in static air at 982 °C (1800 °F) could give a reasonable simulation of long-time power plant operation.

Iron- (Fe-), nickel- (Ni-), and cobalt- (Co-) based high-temperature alloys with sufficient chromium (Cr) and/or aluminum (Al) content can exhibit excellent oxidation resistance. The protective oxides formed by these classes of alloys are typically Cr₂O₃ and/or Al₂O₃, and are usually influenced by their Cr, or Cr and Al, content. Sixty-eight Co-, Fe-, and Ni-base high-temperature alloys, typical of those used at this temperature or higher, were used in this study. (Detailed chemical compositions of these alloys are listed in ref. 1.)

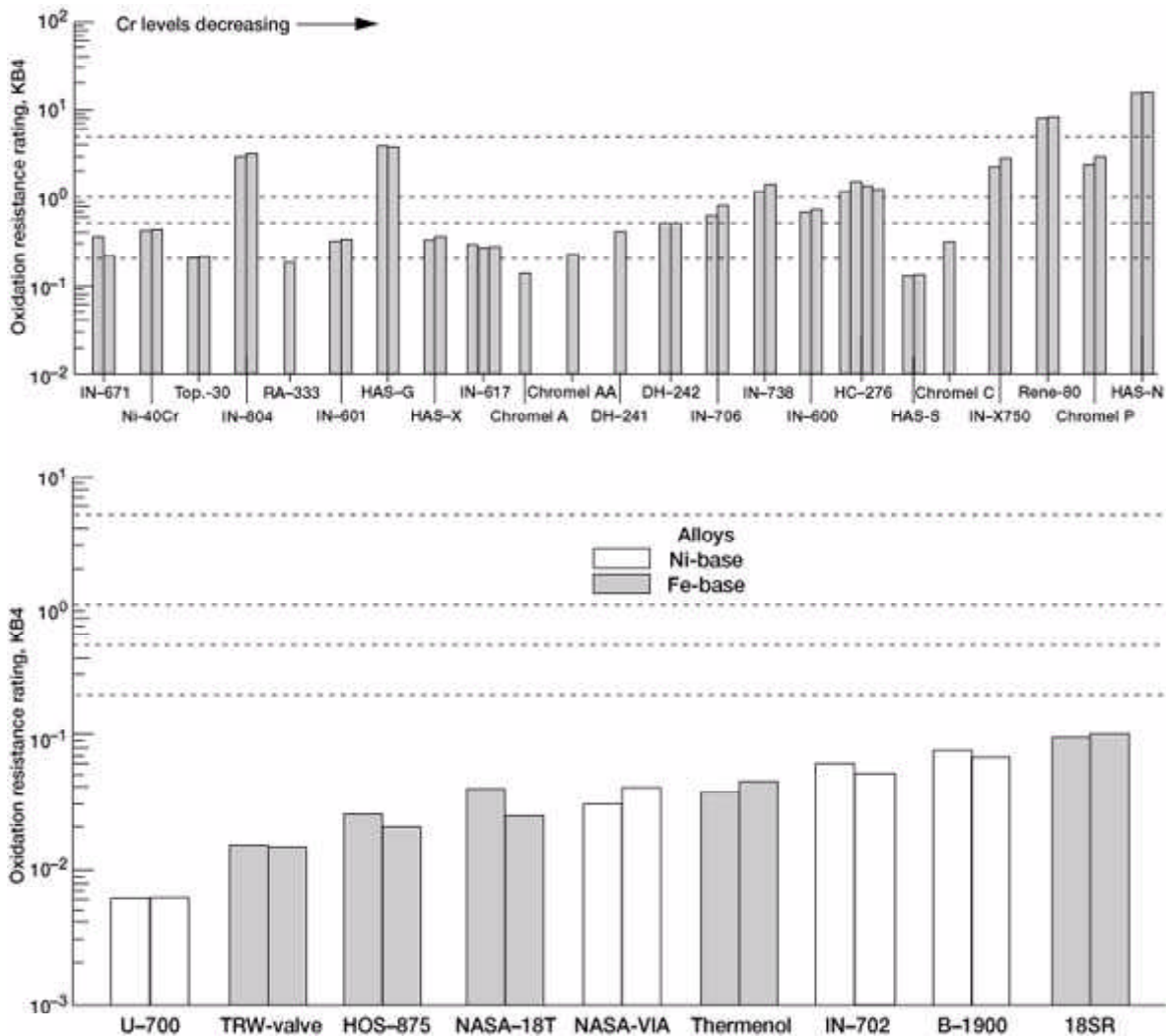
At the NASA Lewis Research Center, the alloys were tested and compared on the basis of their weight change as a function of time, x-ray diffraction of the protective scale composition, and the physical appearance of the exposed samples. Although final appearance and x-ray diffraction of the final scale products were two factors used to evaluate the oxidation resistance of each alloy, the main criterion was the oxidation kinetics inferred from the specific weight change versus time data. These data indicated a range of oxidation behavior including parabolic (typical of isothermal oxidation), parabolic-linear, linear, and mixed-linear kinetics. Parabolic-linear kinetics was the most typical behavior, with scale growth at the operating temperature and scale spalling as the sample cooled between exposure cycles. Of the 132 cyclic oxidation tests (including replicates), 94 indicated parabolic-linear behavior, only 4 showed parabolic behavior (scale growth only), and 34 were linear or mixed linear, where spalling tended to be massive.

The gravimetric data were fit to the basic parabolic-linear equation:

$$\Delta W/A = k_1^{1/2}t^{1/2} + k_2t \pm SEE$$

where ΔW is the change of sample weight (in milligrams) with time, A is the surface area in square centimeters, t is time in hours, SEE is the standard error of estimate by the multiple linear regression method, and depending upon the degree of fit, the significance and sign of the constants $k_1^{1/2}$ and k_2 define the kinetic model. (The use of this equation is discussed

in detail in ref. 1.) The regression coefficients were combined into a single parameter, which along with the alloys' physical appearance, provided a relative ranking of the alloys' oxidation resistance.



Relative oxidation attack resistance ratings. Dashed lines indicate cyclic oxidation resistance ratings, KB4: <0.2, excellent; 0.2 to 0.5, good; 0.5 to 1.0, fair; 1.0 to 5.0, poor; >5.0, catastrophic. Top: Chromia/chromite-forming Ni-base alloys (ten 1000-hr cycles at 982 °C). Bottom: The best of the excellent-ranked oxidation-resistant alloys (ten 1000-hr cycles at 982 °C).

Of the 68 alloys tested, 16 alloys were ranked as excellent, 18 good, 5 fair, 10 poor, and 19 catastrophic. The top bar graph shows 23 Cr-containing Ni-base alloys that formed a protective chromia/chromite scale. The bottom bar graph shows the best of the excellent-ranked alloys. They include four Ni-base and five Fe-base alloys. All of the most highly cyclic-oxidation-resistant alloys were protected by the formation of alumina and aluminate scales.

Reference

1. Barrett, C.A.: 10,000-Hour Cyclic Oxidation Behavior at 982 °C (1800 °F) of 68 High-Temperature Co-, Fe, and Ni-Base Alloys. NASA TM-107394, 1997.
(Available online: <http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?1997/TM-107394.html>)

Lewis contact: Charles A. Barrett, (216) 433-3163, Charles.A.Barrett@grc.nasa.gov

Author: Charles A. Barrett

Headquarters program office: OAT

Programs/Projects: HITEMP